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The Remote Atmospheric Probing Information Display (RAPID) System

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15 January 1988

ATMOSPHERIC SCIENCES DIVISION PROJECT 6670

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"This technical report has been reviewed and is approved for publication"

FOR THE COMMANDER

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The RAPID system has been developed to support short-term forecasting of cloud and precipitation. RAPID was developed with the philosophy that the system should be easily maintained, user-friendly, yet powerful enough to perform both the analysis of radar and satellite data and generation of forecasts in real-time. The two major hardware components are a VAX host computer and an ADAGE RDS-3000 image processor. The RAPID user environment is structured to encourage user participation. Numerous standardization procedures are employed: a functional disk organization, standardized data and source file headers, extensive file documentation, and use of user-developed RAPID "tools," libraries of often-used routines. Data management has been designed to maximize the potential for real-time capability. Radar and satellite data are preprocessed on other computers before ingestion into RAPID. The bulk of these data and derived products are stored, and analysis and display are performed entirely within, the image processor.

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The Remote Atmospheric Probing Information Display (RAPID) System

1. INTRODUCTION

The Air Force Geophysics Laboratory (AFGL) is developing the capability for accurate nowcasting of cloud and precipitation for use in support of general air and terminal operations as well as communication activities. RAPID is a system for generation of such forecasts (0 to 0.5 hr) through the use of continuously updated radar and satellite data. The underlying premise of the forecasting methodology is that future distributions of precipitation may be derived from monitoring and forecasting patterns of selected precipitation intensity.

This effort is part of a larger initiative to develop a multifaceted system to provide 0 to 2 hr forecasts of cloud and precipitation. The more comprehensive effort will also include prediction of cloud development through detection of storm development precursors. Although the system described here is for the 0 to 0.5 hr forecast effort, it has sufficient flexibility to allow for expansion into more extensive forecasting tasks.

One element addressed in the development of RAPID involved system hardware and software and how they could provide an efficient environment that encourages user participation. A second element concerned development of data analysis techniques and associated software to operate within this environment. This re-

(Received for publication 13 January 1988)

port will focus on the system hardware and environment definition, while a second report by Bohne[1] addresses technique development.

2. SYSTEM REQUIREMENTS

Before a specification of the system components could be derived, it was necessary to assess the hardware environment desired. Numerous factors were considered: including hardware and data concerns, the desired operational forecasting environment, the needs of potential users, and the lack of computer support personnel. From these considerations, it was determined that the system hardware must be:

off-the-shelf, that is, requiring no development of unique hardware components;

easy to install and maintain;

supportive of a mature and robust operating system having real-time capability;

of sufficient processing power to allow for processing large data sets in real-time;

reliable;

cost effective, that is, the lowest priced system to meet all the requirements;

expandable to allow for growth.

In addition, the software environment generated by the selected hardware must be:

capable of handling large data sets (12 to 24 Mbytes);

user friendly and supportive of data storage and file standardization procedures;

supportive of software development in higher level languages (for example, "C" and FORTRAN);

supportive of a file management architecture that allows for hierarchical structuring of files;

sufficiently flexible to allow a variety of uses;

supportive of real-time operation.

The RAPID system methodology is intended to include all processes from data ingestion to the generation and display of the short-term forecasts. It was determined that data acquired from remote sensors should first undergo preliminary coordinate conversions on other systems. It was also anticipated that RAPID

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1. Bohne, A.R., Harris, F.I., Sadoski, P.A., and Egerton, D. (1988) Short Term Forecasting of Cloud and Precipitation. AFGL-TR-88-0032.

should be capable of eventually incorporating other short-term forecast approaches such as the use of simple numerical models.

With these considerations in mind, the components and associated requirements considered essential for the system are:

1. A host system
   --with general purpose processor(s) of sufficient speed and memory to process large amounts of data and to allow for manipulation of multiple images;
   --with enough disk storage to allow for several test data sets (typically, 12 Mbytes per set) as well as system and user applications software.
2. An image processor with sufficient memory to store, manipulate, and display multiple images.
3. Communication links
   --between RAPID and other hosts that allow minimum data rates of 9600 bits per second for the transfer of satellite and radar images;
   --between the display and host allowing high speed data transfer via Direct Memory Access (DMA).

The resultant system satisfied the above considerations. It should be noted, however, that the actual process of design was more evolutionary than might be apparent here. Where appropriate, some of this evolution of thought will be briefly discussed to more completely present the RAPID system concept.

3. SYSTEM DESCRIPTION

Within any computer-based system, there are both hardware and software elements. While it is difficult to separate these in many cases, the following discussion attempts to preserve this distinction.

3.1 System Hardware

As outlined earlier, the RAPID system may be described as having three major hardware elements. The overall configuration of the assembled system is shown in Figure 1, and the specific element attributes are discussed in the following sections.

3.1.1 HOST COMPUTER

Digital Equipment Corporation (DEC) hardware was chosen for the host system because it best satisfied all of the stated requirements. In particular, DEC systems were easy to install, required no special hardware development to allow integration of other components, and fulfilled all software requirements. Initially, a DEC VAX 11/750 served as host to the RAPID system. It had 4 Mbytes of mem-

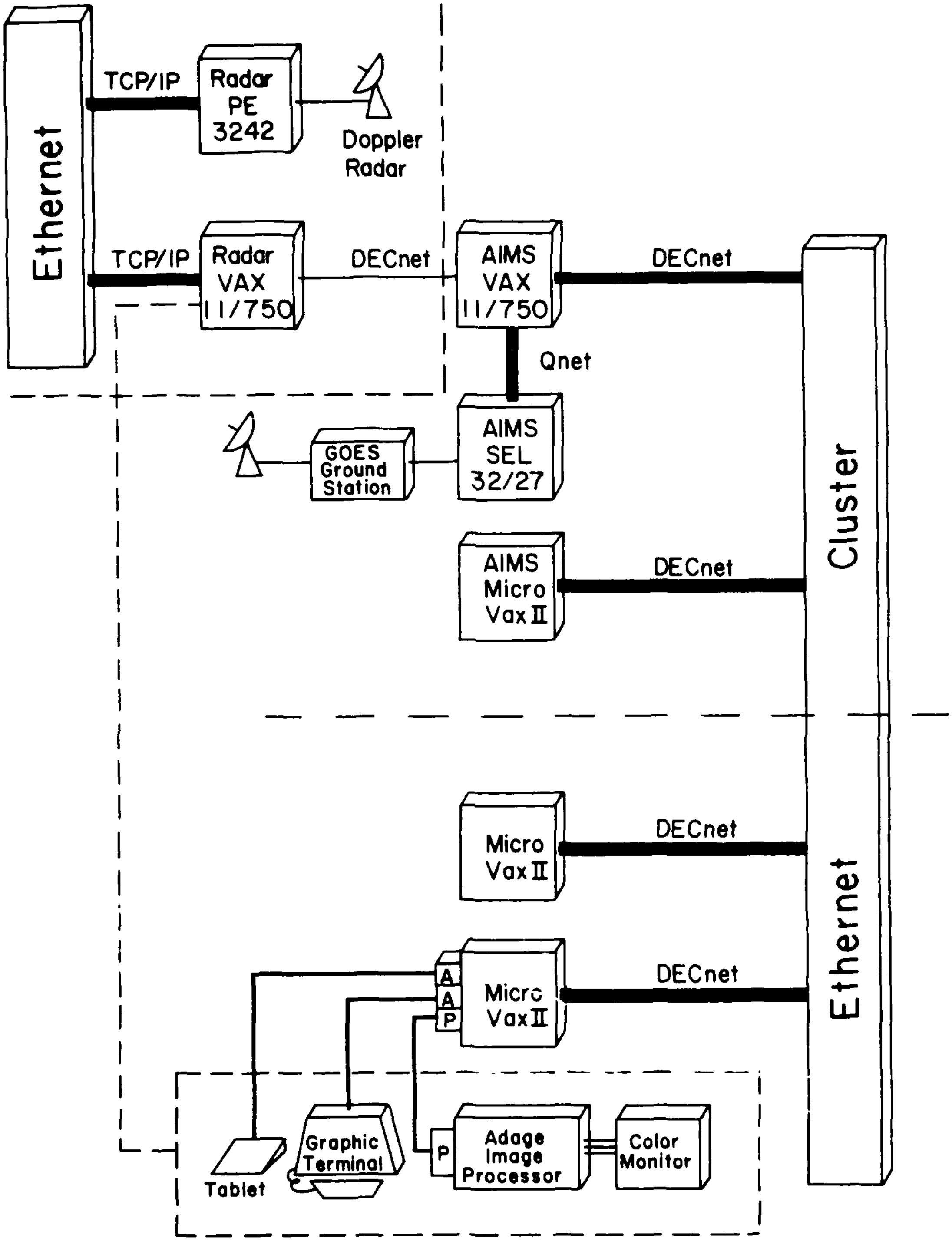

Figure 1. Schematic Representation of Processing Hardware and Communication Links Pertaining to the RAPID System. Hardware in center right are part of AFGL AIMS, while that below constitutes RAPID. Hardware in the upper left is located at the AFGL radar facility in Sudbury. Dotted lines indicate RAPID configuration in initial developmental stage.

ory, a 456 Mbyte disk, 1600 bpi tape, and all standard terminals and I/O devices attached. It also had a synchronous serial line that connected RAPID to the AFGL Interactive McIdas System (AIMS) VAX at Hanscom Air Force Base. The above equipment is located at the AFGL Ground-Based Remote-Sensing Site (LYR) in Sudbury, Mass.

Subsequently, the RAPID system has been relocated to the AFGL Hanscom AFB site. Currently, a DEC MicroVAX II serves as the RAPID host computer, and the ADAGE image system has been transferred to this new host. Figure 1 shows this current configuration and how it relates to the original system configuration. The new RAPID VAX host has twice the memory and twice the performance of the original host. The Sudbury VAX is now being used to communicate radar data from Sudbury to the RAPID System. The only hardware adjustment required for the RAPID relocation was a new DMA controller board to connect the ADAGE to the MicroVAX. Since hardware expansions, upgrades, and changes have been so easily accommodated, the validity of selecting this hardware configuration has been verified.

3.1.2 IMAGE SYSTEM

The imaging system consists of the ADAGE RDS-3000 display system, monitor, and camera (Figure 2). Within the ADAGE are two distinct components: a video display unit and an embedded bit-slice processor (BPS). This configuration allows for a high degree of parallelism during operations. For example, while video display operations from display memory are occurring, the same memory can be independently accessed by both the host computer and the embedded BPS.

Currently, the ADAGE video display system contains 8 Mbytes of image memory allocated into two "pages." Each page is organized as a 1024- by 1024-(x, y) pixel plane with each pixel location 32 bits deep. Within this configuration, any contiguous pixel block, up to 512 by 512 pixels, is viewable at a 60Hz refresh rate, and each pixel is addressable via its (x, y) coordinates. In addition, each page may be thought of as 32 single-bit planes of 1024 by 1024 pixels. Images can be stored on any single or contiguous combination of bit planes, thereby allowing the storage of multiple images of varying depth (for example, 1, 2, 3, etc. bits deep) in one (x, y) region.

To view images, the data are first written to the image memory by either the ADAGE BPS or the host computer. A 512- by 512-pixel 32-bit image can be written (or read) in approximately 3 sec. While the ADAGE employs a 32-bit-wide data bus, the user can control which of the 32 bits are accessed in memory. From the video memory, the image data goes to the frame buffer controller (FBC) where software parameters select the viewing window location, size, aspect ratio, and magnification. From the FBC, the image data passes to the crossbar switch

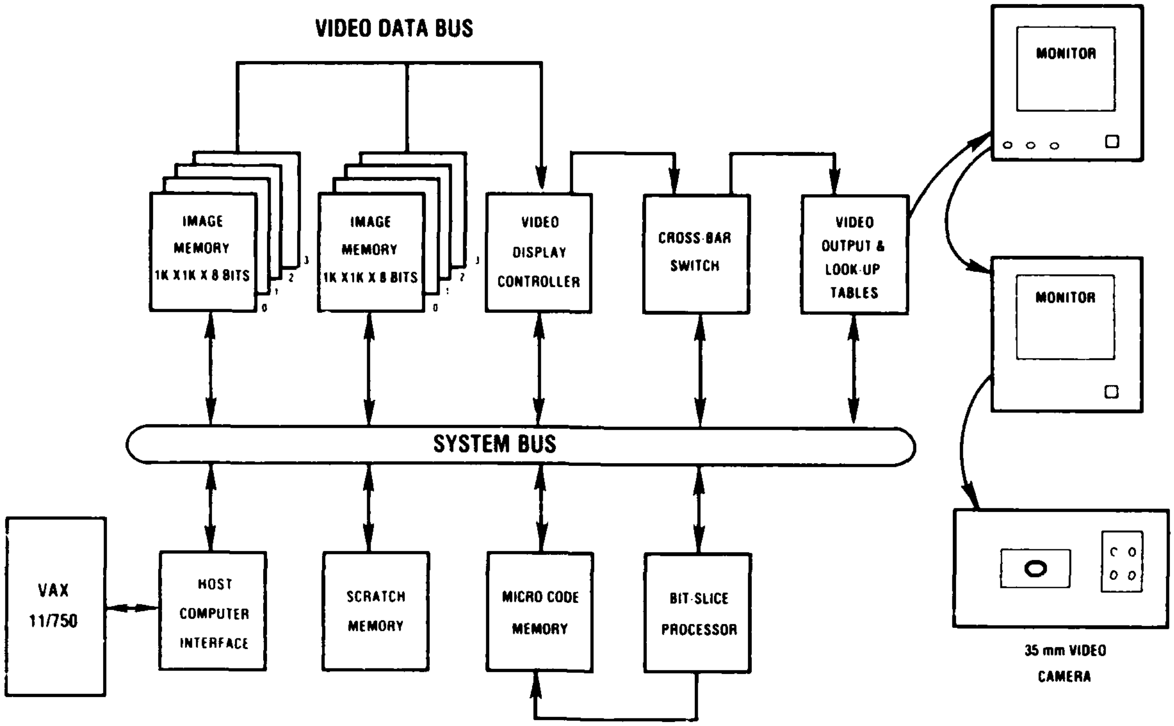

Figure 2. Schematic Representation of the ADAGE Image Processor and the Data Flow From Ingestion to Final Display

(XBS) where the bits or bytes to be viewed are software selected via a masking operation. From the XBS, the video data go to the red, green, and blue color look-up table memories and video output circuitry (LUVO). Incoming data values point to locations in the color tables to generate the colors and shades desired. Although it is possible to display over sixteen million different colors (full-color operation), the current configuration employs 256 colors for both display and overlay. This flexibility in data storage (1 to 32 bits of storage per pixel) and display are major strengths of the system.

The ADAGE BPS is used in data and display manipulation by acting as a coprocessor under the control of the host. The host loads routines to be executed into the microcode memory (64 kbytes), which then sends the microcode instructions to the BPS via a separate instruction bus, and then monitors the coprocessor for completion of the routine. These instructions are generated on the VAX with a "C" language cross-compiler to produce the required microcode. Because the BPS can execute multiple operations concurrently (for example, read pixel, shift and mask, and conditional test operations), it has a distinct speed advantage over the host processor. Also, since the BPS is general purpose, it is much easier to use and more flexible than other imaging systems that are more algorithm specific.

On the other hand, algorithm-specific hardware is usually more efficient for their designed tasks.

3.1.3 COMMUNICATION LINKS

There are two external and one internal major communication links required for RAPID operation:

AIMS to RAPID for ingestion of satellite data

PE3242 to RAPID for ingestion of radar data

VAX to ADAGE

The AIMS to RAPID link was first accomplished by means of 9600 baud telephone lines and the use of DECnet. With the relocation of the RAPID system to Hanscom AFB, the AIMS to RAPID link was altered to that of an ETHERNET, where AIMS and RAPID are all part of a Local Area VAX Cluster (LAVC).

The transmission of radar data to RAPID in the original LYR configuration was accomplished by first preprocessing the data on the LYR Perkin Elmer 3242 minicomputer and then passing it to the RAPID VAX hos via an ETHERNET LAN (Local Area Network). Other methods for data transfer were also investigated, such as the radar processor to VAX or radar processor to ADAGE. In both instances, however, in-house construction of specialized hardware would have been required. The networking solution adopted required only the purchase of proven, off-the-shelf equipment. With relocation, the original AIMS to RAPID link via telephone has also been inserted to complete the communication from the PE3242 to RAPID via the AFGL Sudbury Site VAX.

The VAX and ADAGE have been linked through the acquisition of DMA controller boards and associated software for the VAX systems. This allows the rapid two-way communication between these two systems necessary for the efficient sharing of large volumes of data. As already noted, this was the only hardware replacement required to accommodate the change in host computers.

3.2 System Support Software

On the RAPID system, the software is broken into two large bodies, purchased software packages (to control general machine operations, data transfer links, and utility functions) and user-developed software. User-developed system routines for use in the overall RAPID forecasting program are termed RAPID software. This class of software is discussed in Sections 4 and 5.

The purchased packages are naturally maintained as separate entities on the VAX system and require no organizational considerations from the standpoint of disk utilization. This software is loosely identified as support software. As in the discussion of hardware, the system support software may also be discussed with respect to the three main system components. All of the software is

resident on the host computer. The subdivision here simply allows for clearer identification of the applications.

3.2.1 HOST SYSTEM SUPPORT SOFTWARE

The lack of computer support personnel has been a major factor influencing system development decisions. With software the first user interface to the RAPID system, selection of an operating system and software development environment was the first task. A UNIX-based system was considered but was judged not viable for a real-time operating system nor robust enough to be managed by non-computer science-oriented personnel. Alternatively, DEC VMS (Virtual Memory System) was adopted, for it provided the required real-time capability, simply system management, and suitable software development environment. The support software include such items as DEC VMS operating system, FORTRAN and C compilers, and DECnet for VAX-to-VAX data communications.

3.2.2 IMAGE SYSTEM SUPPORT SOFTWARE

Commercial software was acquired to allow for easy and flexible interaction with the ADAGE image system. In particular, ICROSS-3000 (the cross-compiler that creates ADAGE microcode from "C") and Adage-3000 FSS (FORTRAN-supported graphics subroutines in support of the ADAGE) have been acquired and are extensively used in application software. The ICROSS software allows the programmer to develop software for the ADAGE BPS in a high-level language, thereby enabling improved productivity and more effective use of the ADAGE processor. The FSS software consists of FORTRAN callable routines to perform manipulation of display parameters (such as pan, roll, scroll, etc.) and the drawing of simple geometric primitives. These FSS routines also produce microcode that is downloaded into the ADAGE BPS.

3.2.3 COMMUNICATION LINK SUPPORT SOFTWARE

Communication software is required to manage the interaction between the various computer systems. For the ETHERNET communication link between the AFGL Sudbury PE 3242 and VAX 11/750, HYPER-Link software was acquired. This link uses the DoD network communication protocol known as TCP/IP (Transmission Control Protocol/Internet Protocol). Within this protocol, all information transfers are broken into sequences of small messages known as packets. Packets are transmitted over the ETHERNET hardware and reassembled into the original message.

DECnet software was acquired from DEC for the AFGL Sudbury VAX-to-AFGL AIMS link, and the current AIMS-to-RAPID link utilizes LAVC, another DEC software package.

4. THE RAPID ENVIRONMENT

In the development of a RAPID working environment that facilitates both software development and is conducive to the operation of a real-time forecasting system, it has been necessary to adopt certain practices concerning software development and file and data management. These are intended to make the best use of the system hardware and RAPID system software. The most pertinent practices that have been adopted are addressed below.

4.1 Software Standardization

Software standardization procedures are rigidly maintained for all user-developed software. Some examples include use of: "RAPID tools" wherever possible, structured code, extensive documentation, a standard comment header format for all source files, and standard data file headers. An example of a source file header is shown in Figure 3. This header format provides a history of program evolution, various argument terms, and an explanation of how and when to use the routine. Its use allows efficient maintenance of a system library file in which all RAPID system file headers are stored. Reference to this library allows a quick determination of the availability of particular system tools. These procedures are designed to reduce duplication of effort by requiring commonality among all user-developed software.

4.2 RAPID Software Tools

To streamline the software development process, the concept of software tools, an outgrowth of a philosophy developed by Kernighan and Plauger,[2] was invoked. As applied here, this means the development of a set of general-use system routines. Typically, these are derived from user routines after they are thoroughly tested and documented according to the specific documentation standard. With this procedure, software development becomes more efficient and the mechanics of individual programs are more easily understood. Examples of such common tasks include the processing and analysis of satellite and radar data, the loading of color tables into the ADAGE, and reading from and writing to ADAGE display memory. Much of this software is located in object libraries that are assigned when a user logs into the system, allowing for automatic access from any program at link time.

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2. Kernighan, B.W., and Plauger, P.J. (1976) Software Tools, Addison-Wesley, Reading, Mass.

TITLE: PURPOSE/FUNCTION: PROGRAMMER: HISTORY: V1.0 CREATED AT AFGL/ LYR CONSTANT EXPRESSIONS: VARIABLE ARGUMENTS: ROUTINES USED: INSTRUCTIONS FOR USE: CODED VAX/VMS FORTRAN V4.3 NOTES:
DECLARATIONS
IMPLICIT NONE CHARACTER INTEGER LOGICAL REAL
CODE

Figure 3. Example of the Source File Header Adopted for Use With All RAPID System and User Files for Locally Developed Software

4.3 File Organization on the VAX Disk

The VAX disk is organized to allow users access to data and programs in a logical, simple, and expedient manner. The physical disk is divided into several "logical" or virtual disks, where each logical disk is simply a top-level (root) directory with a functionally oriented name (DATA, ANALYSIS, DISPLAY, CONVERSION, or UTILITY). All user-developed system files are similarly categorized and placed in the corresponding system logical disks. When implemented, this gives users the look and feel of having several smaller disks connected to the system. Additionally, the system directories are divided into subdirectories, each subdirectory containing closely related files that logically fall under the associated "root" directory.

4.4 Data File Headers

The processes of VAX disk organization and software standardization naturally led to consideration of data management requirements for image data. Throughout the processes of software development and testing and in real-time operations, large quantities of satellite and radar data and numerous derived products will be processed within RAPID. For efficient data transfer and storage, a standard image data file format was developed for all data, regardless of sources. Data files consist of 256-byte image headers paired with variable size data sets. The reason for having such a global standard format is to allow general purpose software (RAPID tools) to be written to read/write/display all local data without regard to its type.

4.5 Data Management Within ADAGE Display Memory

The requirement for very fast and efficient processing of the satellite and radar image data demands processing these data within the ADAGE BPS. This results from the higher speed of the ADAGE coprocessor over the VAX and the minimization of the number of data transfers between the ADAGE and VAX subsystems. Maintaining data resident within the ADAGE with minimal confusion has led to the allocation of specific areas of display memory for specific types of data, a procedure locally termed "memory mapping." In this manner, the various types of remotely sensed data are unambiguously stored and information about these data is maintained in the "file cabinet," an area set aside to store important attributes of these data fields.

The allocation of data storage in ADAGE memory is determined primarily from the data update rate, the total field of coverage desired, and the data resolution. For example, a complete volume of radar data is collected every 5 to 10 minutes, from which are constructed three horizontal planes corresponding to low, middle, and upper layers of the storm. These three planes, as prescribed by the user, provide a fairly complete description of the three-dimensional precipitation structure. Satellite data, on the other hand, yield one visible and one infrared image every 30 minutes. Therefore, there will be 4.5 to 9 times as many radar images as satellite images.

If we refer to an (x, y) portion of memory (32 bits deep) reserved for data storage as a frame, there is a simple and logical system of data storage. Within each radar data frame, the three planes (each 8 bits deep) of data derived from one radar volume scan may be stored. The remaining 8 bits may then be reserved for overlays. For satellite data, it is convenient to store three successive images, each 8 bits deep, in one satellite data frame. There will then be separate frames for infrared and visible images.

The resulting configuration is shown in Figure 4, where each labeled area is a frame. The map reserves ten frames for radar images for storage of 1 to 2 hours of data, depending on the frequency of collection, and one frame each for visible and infrared images for storage of 1 hour of satellite data. Generally, radar data are stored with a resolution of 2 km, while satellite infrared and visible data utilize resolutions of 4 km and 2 km, respectively. To obtain a viewing window of 512 by 512 km of data, frames of 256 by 256 pixels each for radar and visible satellite, but only 128 by 128 pixels for infrared, are required. The second page of display memory has been reserved for use as a general work area.

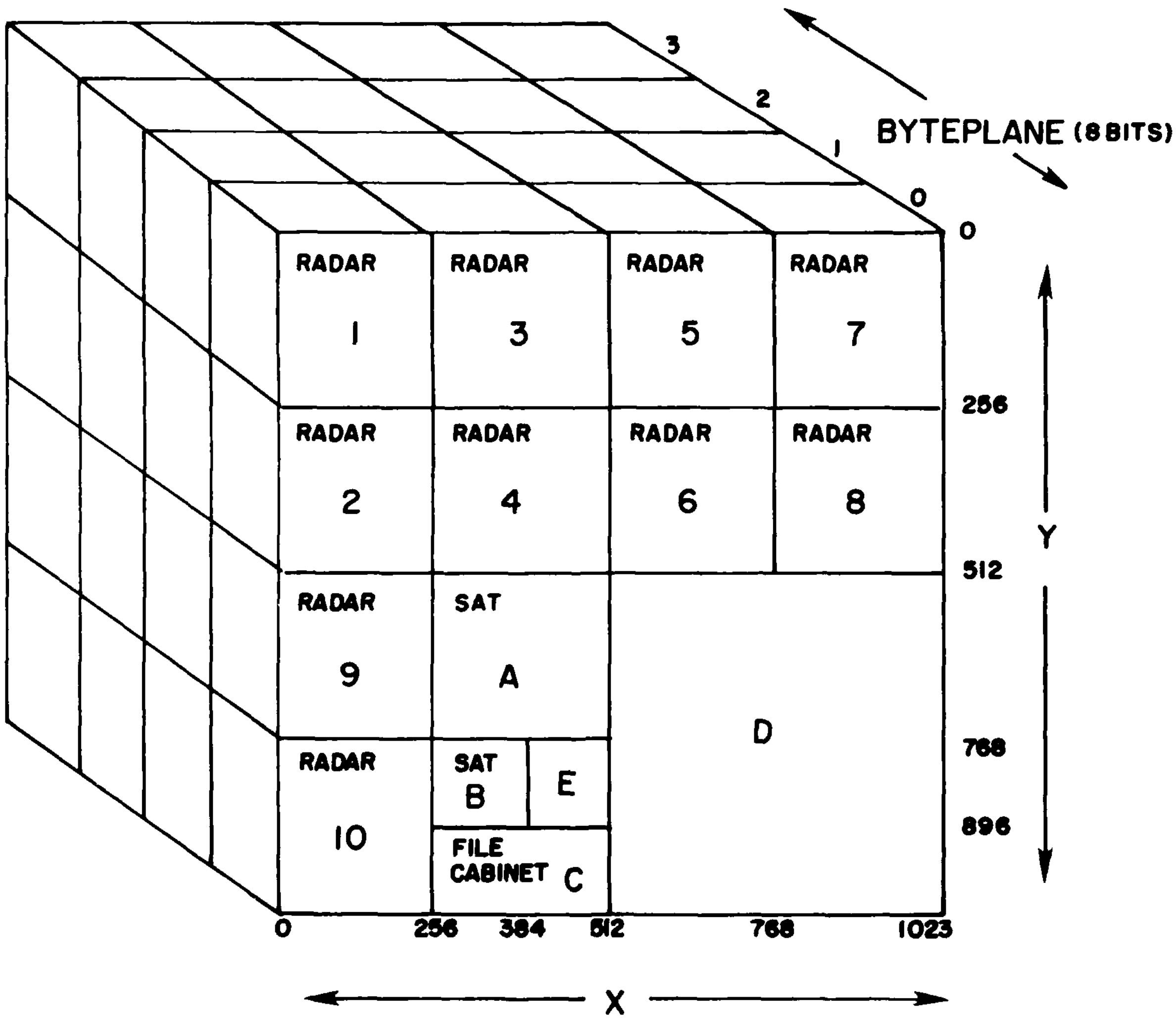

Figure 4. Memory Mapping for the ADAGE Indicating Sizes, Locations, and Contents of Frames

The RAPID "file cabinet" was developed in order to retain within the ADAGE itself the type, location, and attributes of all data currently stored in display memory. This directory can be accessed by programs running on the BPS and host at any time. For each image stored in display memory, there is an entry (256 bytes long) in the same byteplane in the file cabinet. With this organization, new data may be automatically directed to the proper storage location, and analysis programs running in the BPS need only search the resident file cabinet to locate the pertinent data for subsequent analysis. This approach should aid in optimizing the analysis and forecasting processes in the development of real-time nowcasts.

5. RAPID SOFTWARE

RAPID software represents system programs and packages developed by the users locally and those obtained from other user groups. These software include a large variety of routines ranging from pure data analysis procedures through utility functions. After the user software is debugged, tested, and fully documented according to the standardization guidelines mentioned earlier, both the source and object code are migrated from the user directory into the appropriate functionally identified RAPID system directory. The following description is not all-inclusive, but is presented to highlight the more significant components.

5.1 General Purpose Libraries

The development of functionally oriented object libraries is one facet of the software standardization program. They are logically assigned as default link libraries when a user logs into the system, so that they can be accessed automatically from any program at link time. Object libraries now existing on the system include the following:

ANALYSIS: [PROD. VAX]ANALYZE_ON_VAX. OLB includes locally written software that perform data analysis in VAX memory. For example, it includes routines that locate data contours and extract contour boundaries, describe the contour boundaries in terms of directional chain codes, and determine basic parameters such as the relative maxima and minima or the center of area of a contour given its chain code, or the (x, y) coordinates of the point for a given code of the chain.

UTIL:[IO]IOLIB. OLB includes locally written software that performs various I/O functions between the VAX and peripherals including disk, tape, and the ADAGE BPS.

ANALYSIS:[PROD. ADAGE]ANALYZE_ON_ADAGE. OLB includes locally written software that performs data analysis using the ADAGE image processor. Ex-

amples would include routines to generate a contour silhouette or outline given its chain code, to filter data for the purpose of noise removal and smoothing, to reduce or replicate displayed data, to clear the display, to subtract two images, to calculate the histogram of a displayed image, etc. Many of the routines in this library are written in ICROSS.

DISPLAY:[TOOLS]IK.OLB contains locally written software that performs various utility functions in the ADAGE. This includes routines that set/get register values, load color tables, save/restore display memory to/from disk, set the crossbar switch, and display colors.

UTIL:[MISC]DRAWLIB contains locally written software that performs primitive graphics operations, for example, line-drawing, circle and ellipse generation, and character generation (three fonts available). All display data are generated in integer or byte arrays that can then be displayed on the ADAGE or saved to disk as needed.

5.2 FTEST

To test the boundary feature algorithms, an interactive software package, FTEST, was developed. FTEST has evolved into the main driver for the RAPID system forecasting package and will control the concurrent display and analysis of satellite and radar data. This package includes the routines used in the feature extraction and mapping and is being modified to include the forecasting algorithms. Typical routines include data thresholding and filtering, contour extraction, chain code development and matching, simple exponential and one-parameter linear trend extrapolative forecasting, and contour reconstruction. The program is completely modular and menu-driven.

5.3 SHOWSAT

SHOWSAT is a software package that allows manipulation of satellite images interactively. The program is completely modular and menu-driven and contains display, processing, and analysis routines. While it was originally designed for standalone performance, modifications have been made for its incorporation into an overall RAPID processing package built around FTEST.

5.4 Hewlett-Packard Plotter Software

Hard copy plots may be obtained through use of the Hewlett-Packard 7545 six-color pen plotter. A number of standardized software packages have been developed for plotting line graphs and data contour features on gridded or non-gridded backgrounds. Additional software has been written for use with chain code data, for plotting features such as segments of chain code, and time sequences of chain

code boundary segments. These plots aid greatly in analysis of data and in the development of mapping techniques. In addition, presentation software packages are being developed for the generation of multicolor viewgraphs and other presentation materials.

5.5 Demo Program

To illustrate the concepts and work being performed on the RAPID system and some of the special techniques being developed at the site, a RAPID demonstration program was written. The demo program is menu-driven and provides a visual display on the ADAGE display monitor.

5.6 NCAR Graphics

A graphics package was acquired from the National Center for Atmospheric Research (NCAR) that is device-independent, and thus can be used to produce graphics on the ADAGE, the Hewlett-Packard pen plotter, or any other graphics device that is obtained in the future. This package has been used extensively in data contour plotting and display.

5.7 NCAR Radar Analysis Package

A software package for processing radar data was obtained from NCAR, installed on the VAX, and the graphics output was interfaced with the ADAGE. Some of the characteristics of this package are described in Mohr and Vaughan,[3] Mohr and Miller,[4] and Mohr et al.[5] Basically, the software can read data from a variety of sources (for example, NCAR radars, NOAA/NSSL radars, etc.), convert them to a common format, and interpolate the data to a rectangular Cartesian grid. The resultant fields can then be manipulated, edited, analyzed statistically, and combined with data from other radars to produce combined products like three-dimensional wind fields. At any point, a variety of graphical or printed displays are available. While this analysis package will not be included directly in

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3. Mohr, C.G., and Vaughan, R.L. (1979) An economical procedure for Cartesian interpolation and display of reflectivity factor data in three-dimensional space, J. Appl. Meteorol. 18:661-670.

4. Mohr, C.G., and Miller, L.J. (1983) CEDRIC--software package to Cartesian space editing, synthesis and display of radar fields under interactive controls, Preprints, 21st Conference on Radar Meteorology, American Meteorological Society, Boston, Mass., 569-674.

5. Mohr, C.G., Miller, L.J., and Vaughan, R.L. (1981) An interactive software package for the rectification of radar data to three-dimensional Cartesian coordinates, Preprints, 20th Conference on Radar Meteorology, American Meteorological Society, Boston, Mass., 690-695.

the RAPID software package, it has proven very useful in generating radar Cartesian fields for testing algorithms and as a model for the real-time interpolation package developed for the AFGL Ground-Based Remote Sensing Site's Perkin Elmer computer.

6. DATA FLOW OVERVIEW

With the hardware and software elements of the RAPID system clarified, it is useful to examine the data/product flow into and among these elements. Figure 1 shows the RAPID system linked to two other systems from which radar and satellite data are obtained. The Doppler radar data is received from the AFGL 10 cm Doppler radar in Sudbury, Mass. The raw radar data are first processed in the Doppler radar processor resulting in a final output data rate of about 0.3 samples per millisecond. These data are passed to the PE 3242 minicomputer, where the reflectivity factor data are interpolated to a Cartesian grid format. The resultant fields are transferred to the Ground-Based Remote Sensing Site VAX 11/750 via ETHERNET. Originally, this was the route to RAPID. Currently, these data are subsequently shipped to the AFGL AIMS VAX cluster via DECnet and then to the microVAX workstations used in this project. This procedure makes good use of the Ground-Based Remote Sensing Site PE 3242 with its large memory, high speed, and large disk storage capability, significantly reduces the data flow among the various nodes, and frees the RAPID system from the time-consuming radar data assimilation task.

Similarly, data are received by the RAPID system from the AIMS VAX cluster network. AIMS routinely acquires data from the GOES satellite and a number of standard surface-based weather reporting stations. The satellite imagery data are "filtered" within AIMS to focus on the area of interest (roughly a 512 by 512 km region) centered about the Sudbury radar location prior to its transmission to the RAPID system.

When the RAPID host receives a new satellite or radar image, it is downloaded to the ADAGE subsystem. These data are automatically written to specified locations in the ADAGE display memory and catalogued in the ADAGE "file cabinet." With the data now resident within the ADAGE, automatic or interactive processing through either the ADAGE BPS or VAX host system is performed and the products displayed on a high-resolution color monitor. These data may also be copied to the host disk for archiving.

A review of the various data processing and analysis procedures adopted in RAPID may be found in Bohne et al.[1] Currently, both FTEST and SHOWSAT are being utilized in the methodology. Efforts are under way to fine tune analysis

routines and develop a real-time executive program to control the complete data flow from radar processor through display of final forecasted precipitation field distributions.

7. SUMMARY

The RAPID system is being developed as a tool for providing short-term forecasts in real time. The system is designed with the philosophy that hardware and software should be easily maintained and that program development should be performed within a user-friendly environment. In terms of hardware, this has resulted in the acquisition of powerful, user-friendly, yet versatile off-the-shelf components: a Digital Equipment Corporation VAX-based computer as host, and an ADAGE RDS-3000 for image processing.

From the software perspective, this philosophy has resulted in the development of a structured programming and database management environment that results in enhanced maintainability and reliability. Elements of this environment include a functional disk organization, program and subroutine source file headers, common database management routines, common interface routines, common display routines, and a well-established calling standard for display system manipulation. The result has been the development of an environment conducive to software development by scientists as well as programmers.

To facilitate real-time operation, a number of steps have been taken. Radar and satellite data are preprocessed on other minicomputers prior to shipment to the RAPID host computer. These data are downloaded into specially allocated regions within the ADAGE display memory where approximately 2 hours of data may be stored. The major portion of the analysis is offloaded to the high-speed ADAGE coprocessor to act on data resident in display memory. This maximizes the effectiveness of the computationally faster image processor and minimizes the number of data transfers between computer components. Current efforts include fine-tuning routines and the development of a real-time executive manager to direct all data processing steps from data ingestion through final forecast product display.

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